Effect of biological agents on survival rate and root growth of Scots Pine seedlings

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Abstract: Two-year-old Scots pine (*Pinus sylvstris* var. *mongolica*) seedlings were treated with Pt mycorrhiza powder, ABT root-growing powder, HRC water-absorbing agent and high-yield powder, and planted on the sandy land in Balinyouqi, Inner Mongolia (180°12'13"E and 43°13'05"N). The effect and function of these biological agents on survival rate of seedlings were tested and analyzed by measuring the fine root growth and gross root growth. The results showed that the survival rates of the seedlings treated with Pt_3, ABT, and HRC biological agents increased by 29.3%, 23.6%, and 16%, respectively. The regression analysis revealed that the length of fine roots (<2 mm) was positively correlated with seedling survival rate, which means that the Pt_3 powder, ABT foot-growing powder and HRC water-absorbing powder increased the survival rates of the seedlings by promoting the growth of fine roots.

Keywords: Biological agents; *Pinus sylvstris* var. *mongolica*; Sandy soil; Roots; Survival rate

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Introduction

Arid and semiarid areas occupy 52.5% of the total land in China (Li 1990). The originally frangible ecological environments have become more deteriorated due to the unreasonable exploitation and utilization of the resources over a long period (Li 1990). The "Three North" ("Three North" means Northwest, Center North central and Northeast regions of China) Protective Plantation System Project ('TN'PPS) is aimed at building up an ecological and economical protection forest system on severely sand-blown and soil eroded arid and semiarid areas of the three North regions through planting trees, growing grass, and recovering and developing a vigorous vegetation to control the damages caused by wind and sand, and to improve the ecological environment and economic factors (The Construction Bureau of the "Three North" Protective Plantation System 1990). The Horqin sandy land, located in northeast of China (42°41'-45°15'N, 118°35'-123°30'E, 180-650 m above sea level), has undergone severe desertification over the past decades due primarily to over-grazing and over-cultivating (conversion of grassland to farmland), (Zhu *et al.* 1993). In the past, most planted poplar, such as *Populus simonii* x *P. ngra*, have developed into the dwarf trees sparsely distributed on the thin stands, because of improper selection of species and low survival rates (Li 1990). *Pinus sylvstris* var. *mongolica* has proved to be one of the most proper species on the sandy land since its successful introduction into Zhanggutai Town, Zhangwu County, Liaoning Province (the southeast end of the Horqin sandy land) from Honghuaerji of Hulunbeier sandy land, Daxingan Mountains, Inner Mogolia in 1955 (Zhao 1958; Feng *et al.* 1986; Zhang 1994). However, the survival rate of the seedlings was low at the new plantation field because of the lower soil water content and severe transpiration caused by higher temperature and severe wind in spring (Wu *et al.* 2003). Biological agent is a regulator used for increasing survival rate and root growth with small dosages. The purpose of this study is to check how the biological agents could enhance the survival rate of the seedlings of Scots Pine.

Study site

The experiment was conducted at Huriha village, Balinyouqi (180°12'13"E and 43°13'05"N) in Inner Mongolia, P. R. China. The area is located at the northwest of the Horqin sandy land and belongs to the continental semi-arid monsoon climate in the temperate zone with windy and dry winters and springs and comparatively rain-rich summers followed by short and cool falls. According to the statistics (1965-1998) of the Balinyouqi Weather Station, the annual accumulative temperature over 10 °C is around 2 996 °C, the annual average temperature is 3.5 °C, and the annual

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frost-free period is 135 days. The annual mean precipitation is 344 mm, and the annual pan-evaporation is 2 200 mm. Although around 85% of the total annual precipitation falls in the growing season from April to September, frequent drought is the limiting factor for the growth of sandy land vegetation (Li 1996). The zonal soil type is windy sand with light yellow color, coarse texture and loose structure; the average organic matter content is 0.615% and total nitrogen content, 0.0327%; water dissolved potassium, 38.6 ppm; total phosphorus content, 0.0135%; total potassium content, 2.48%. The principal agricultural and forest hazards in this region are drought and wind damage. The pH value of the soil is 7.39; overall soil porosity, 32.05%, with a non-capillary porosity of 5.55% and capillary porosity of 26.50%. The vegetation is dominated by *Caragana korshinski*, *Artemisia lavandulafolia*, *Bothrcha ischacman*, *Aneuroloepidium chinese*, *Caragana microphylla*, *Stipa grandis*, etc., with companion species of *Chemopodium album*, *Saposh nikoria*, *Salix pammoplila*.

Materials and methods

The biological agents used were ABT (root-growing power for increasing the root growth), Pt_3 (a kind of powder of mycorrhiza for promoting the formation of mycorrhizal root), Pt_1 (other kind of powder of mycorrhiza acting as the same function as Pt_3), HRC water-absorbing agent for absorbing and maintaining water around the roots, and HYP (high-yield powder for increasing the growth of above-ground part of plants). The 2-year-old seedlings of healthy Scots Pine (*Pinus sylvstris* var. *mongolica*) were taken from Hansan Nursery in mid-spring (19 April, 1997) and their roots were directly treated with the different solutions of the biological agents. The seedlings were designed by randomized blocks method with 3 replications and 6 treatments in the field experiments. All the seedlings were immediately transplanted in the experimental field after being treated with the biological agents. The soil was prepared in the strip pattern and the experimental field was irrigated. The survival rates of treated seedlings were investigated in next spring. Root lengths of all the seedlings randomly selected was measured according to the fine roots (basal diameter <2 mm) and the coarse roots (basal diameter>2 mm), (Yang *et al.* 2002; Ford *et al.* 1979); the root basal diameters were measured with caliper. The data investigated were analyzed by the statistics.

Results and discussion

Survival rates of seedlings planted in the field

The result showed that the survival rate of seedlings varied with different biological agents. To make it suitable for variance analysis, the survival rate is translated into trigonometric function (x_{ij}=arcsinx_{ij}). Based on the arcsine values of the survival rate, the variance analysis results showed that the differences between each treatment were significant while there were no significant differences between the blocks (Table 1). The survival rate of seedlings treated with Pt_3 was the highest, with ABT the second and with HRC the third (Table 2).

Table1. The variance analysis table of the survival rates of Scots Pine seedlings treated with the different biological agents

Resources	Sum of squares of deviations	Free degrees	Mean squares	Ratios between mean squares	F_α
Treatments	761.1665	5	152.2333	31.18*	$F_{0.05}(5,10)$=3.33 $F_{0.01}(5,10)$=5.64
Blocks	6.6457	2	3.3229	0.680	$F_{0.05}(2,10)$=4.10 $F_{0.01}(2,10)$=7.56
Errors	48.8293	10	4.8829		
Total	857.2365	17			

Table 2. Mean survival rates of Scots Pine seedlings treated with the different biological agents (%)

Repeats	ABT	HRC	Pt_3	Pt_1	HYP	CK
	67±10.2	65±9.8	74±9.7	45±6.3	38±5.8	49±8.6
	71±11.3	60±7.9	71±8.9	38±5.6	45±6.2	41±7.3
	66±10.5	57±7.6	77±10.3	46±7.6	41±4.3	44±6.7
Average	68.3±10.6	60.7±8.2	74.0±9.9	43.0±6.4	41.2±5.1	44.7±7.0

Notes: Values over are mean ± SE (standard error).

Effects on root growth

The variance analysis reveals that the difference in fine root growth between each treatment was significant, (Table 3), while the differences in growth of the main roots and coarse roots between each treatment were not significant. From the comparative table (Table 3) we can see that the sequence of effects of the varied biological agents on the root growth is similar to that of the survival rates.

Correlation relationship between survival rates and the different roots

The following multivariate equation of linear regression was derived.

$$Y=-30.1416-0.882X_1+0.1489X_2+0.7951X_3 \quad (1)$$

complex correlation coefficient for $R=0.8861^{*}$; Partial correlation coefficient for $r_{(01)}=-0.0115$, $r_{(02)}=0.1615$, $r_{(03)}=0.6741^{*}$.
where, Y is survival rate of seedlings; X_1 is main root length; X_2 is coarse root length (basal diameter>2mm); X_3 is fine root length (basal diameter<2mm). The main root length was negatively correlated with Y, and coarse root length was positively correlated with Y, but not significant. The fine root length is positively correlated with Y and it is significant ($P<0.05$).

Table 3. The comparisons of lengths of fine roots of Scots Pine seedlings treated with different biological agents (cm)

Symbols	Treatments	Average values	X_i-X_6	X_i-X_5	X_i-X_4	X_i-X_5	X_i-X_6	X_i-X_6
X_1	Pt_3	99.37	19.19^{**}	18.41^{**}	17.77^{**}	8.20^{**}	3.81^{*}	0
X_2	ABT	95.56	15.38^{**}	14.60^{**}	13.96^{**}	4.39^{*}	0	
X_3	HRC	91.17	10.99^{**}	10.21^{**}	9.57^{**}	0		
X_4	CK	81.60	1.42	0.64	0			
X_5	Pt_1	80.96	0.78	0				
X_6	HYP	80.18	19.19^{**}					

Notes: $LSD_{0.05}=3.742$; $LSD_{0.01}=5.086$.

Conclusions

At the sandy soil of the semiarid and arid regions, application of Pt_3 powder and ABT foot-growing powder can significantly increase the survival rates of Scots Pine seedlings planted in the field by 29.3% and 23.6% respectively. The Pt_3 powder, ABT foot-growing powder and HRC water-absorbing powder increase the survival rates of the seedlings by promoting the growth of fine roots. The regression equation shows that the length of the fine roots is significantly and positively related to the survival rates, but the length of main roots and coarse roots has no significant change. Therefore, the biological agents should be encouraged to use widely in the construction of the "Three North" protective plantation system in the semiarid and arid sand areas.

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